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THE FUNCTION OF THE SEVERAL SENSES IN THE MENTAL LIFE¹

By EDMUND C. SANFORD

In the following paragraphs the author attempts to sketch the functions of the several senses in the general mental economy, in somewhat the fashion in which a field naturalist might describe the rôles of the several forms of animal and vegetable life in some district under his observation. He begs the reader's indulgence, therefore, if he speaks first for a moment about well-known matters in order that both may start from common ground.

We have, as everybody knows, sensations of sight, hearing, smell, taste, and touch, sensations arising from posture and movement, and in addition, sensations of pain and indefinite general and organic sensations. We know that through these in various measure we receive impressions from the outer world and from our own bodies, that in response to data furnished by them we adjust ourselves to the world about us by means of movements and that in images derived from them we do a large part, at least, of our thinking.

Our first question is: *What part of these images, in which we do our thinking, does each sense furnish?* We are not especially interested to follow back the sensory elements to their utmost simplicity, but rather to study them in their combinations, in the perceptive and other complexes in which we always find them when we can actually observe them.

Let us take the senses one by one beginning with touch.

Touch is a sense world in itself. We group together under that name sensations of heat, cold, pressures and contacts,

¹ This essay has been read, in substantially the form in which it here appears, as a lecture before the departments of psychology in several colleges and universities. Besides the works referred to in the text, the following have been drawn upon in its preparation:

Obersteiner: *Zur vergleichenden Psychologie der verschiedenen Sinnesqualitäten*, Grenzfragen d. Nerven- u. Geisteslebens, VI, 1905, Heft 37, I-55.

Kant: *Anthropologie*, Werke (Hartenstein Edition), VII. 465ff.

Wundt: *Grundzüge d. physiol. Psychologie, passim*.

Ribot: *Evolution of General Ideas*, tr. by Welby, Chicago, 1899.

The author would also note his indebtedness to his friend Professor Henry Taber of the Mathematical Department, Clark University, for helpful suggestions.

all of which show local differences as one part of the skin or another is stimulated. From the dermal surfaces we also get pain of a definite kind. In active touch we not only have these passive experiences, but a whole new set as well, giving us information as to the position and movements of our members.

Passive touch is a sense of great immediacy. With the partial exception of heat and cold, it responds only to excitations that are applied directly to the skin itself and reach the nerves directly, or through but few intermediaries, as simple mechanical excitations. Mechanical stimuli must of course, like all other kinds, suffer transformation into nervous processes before they can reach the conscious levels of the central nervous system, but this simplicity and immediateness are not without their significance.

Touch resides in what is by far the most extensive of the sense organs,—the whole dermal covering of the body and much of the mucous surface,—and what is still more important, it has a very close and varied connection with the muscles. It has been plausibly conjectured that an important factor in the tactful "local sign" or special difference in character by which any given dermal impression is referred to the one part of the body surface to which it belongs, is a reflex tendency to bring the hand to the spot stimulated or to turn the eye so as to look at it. The same motor connection is shown by the violent start of surprise that follows an unexpected touch. There is hardly anything that will produce a more violent and general muscular contraction than a fully unexpected slap upon the shoulder. The shortness of touch reaction-times probably points the same way, as do, certainly, the variety of reflexes that follow dermal and mucous excitations. All this in the case of mere passive touch,—where the sensory surface simply receives what comes to it. With active touch the connection is still more intimate. The inner touch sensations (the capsular, muscle, and tendon sensations) are not only directly dependent upon bodily movements for their specific stimuli, but supply one of the handles by which we manipulate our members in voluntary movements. Interference with the usual inflow of sensations from the members in movement makes the movements themselves uncertain or impossible, except as vision serves as a vicarious guide. Touch, active and passive together, is pre-eminently the sense of closest motor connections. This also has its important meaning in the psychic life in general.

In another particular the sense of touch is peculiarly endowed. It is the only sense that has an organ that can

be doubled upon itself. The eye cannot see itself; the ear cannot hear itself; nor the tongue taste, nor the nose smell itself; but the hand can pass over the whole body surface, and in so doing both feel and be felt. The eye can, in a secondary fashion, see the body surface and follow and guide the movements of hands and feet, and the ear can hear and control indirectly the sounds that the vocal apparatus produces; but the touch surfaces alone can perform in perfection this ultra-philosophic feat of being at one and the same time both subject and object. The feelings of double contact that arise when two touch surfaces are brought together have, like the immediacy of stimulation and the close connection with muscular movement, a special meaning in the psychic life in general.

Touch has also other characteristics that are perhaps worth mentioning in passing, though their connection with our main problem is not so close. In power to stir emotion the sense stands high. A cool plunge into a swimming pool, the warmth of an open fire, a caress on hand or cheek, the kiss, the embrace, the shock of personal assault all testify to this. Touch is intimate; what stimulates our dermal surface concerns us closely. It touches us in more senses than one.

Touch is a sense in which man exceeds most of the animals. Others may excel him in keen discrimination of odors; perhaps others in vision; but few can compare with him in touch. It is hardly necessary to recall the general covering of fur, feathers or scales that most of the other animals have, and the inadequacy of fins, claws, paws, lips, or even of proboscies, for fine palpations. And with the monkey tribe the hand, though ready in form for touching, is not yet free from general bondage to locomotion. There are a few exceptions. Prof. Whitman has showed an astounding sensibility to touch or jar in certain leeches; but as against most animals man's superiority still holds. Manual deftness in the surgeon or in the engraver is not alone a matter of eye and of muscle but of refined tactful sensibility as well.²

² I remember reading many years ago of a cracksman who was able by touch to discover the combinations of the safe locks then in use. He scraped down one of his finger nails almost to the quick, and holding this against the lock was able to perceive the faint jars produced by the movements of the inner parts of the lock as each was brought to the point required for opening. To learn the combination was then but a matter of a few trials, and the safe was open. Whether this story is true, I do not know, but there is no *prima facie* impossibility in it. At all events the main point stands that the hand is not alone a tool-holding mechanism but a sense organ of high power.

Touch is also a very ancient sense. It begins far back in the animal series, and is active from very early in the individual life history—at first in the tongue and lips, later in the hands and fingers. It is perhaps a mistake to regard it as the mother sense of all the other senses, as is sometimes done. The unicellular creatures react to light and chemical excitants as well as to contacts; and one is hardly justified in saying that everything comes from touch more than to say that everything comes from the primitive capacity to see or to taste and smell.

Nevertheless the statement seems to carry some truth with reference to two of the senses, the rotational-equilibrium sense and the auditory sense, both of which have their end-organs in the inner ear. The morphological series that connects the one with the other seems to have been made out with some exactness. The dermal surface first develops a little sensory pit which later in the series becomes closed in and sometimes contains a granule of calcareous matter. The organ thus formed serves indifferently as an organ for sensing bodily movements or for shocks and jars coming through the surrounding medium. To serve one of these functions come, in course of differentiation, the semicircular canals of the inner ear and their connected parts, still an organ for the indirect regulation of bodily movements, especially those involving rotation and the maintenance of equilibrium, and for the other, much later, the cochlea and the mechanisms responsive to the aerial jars that we sense as sounds. The functional relation is so close between the kinæsthetic organs of the inner ear and those of inner touch (the capsular, muscle and tendon senses) that the derivation seems not unnatural.

In the case of the auditory part of the ear the connection is much more remote. The auditory part of the ear is at most the grand-daughter and not the own daughter of the sense of touch. And yet it maintains at one or two important points the family resemblance. It is still a mechanical sense and responds to actual mechanical impressions upon the nerves, though very delicate ones, and it is very closely connected with the general muscular system both in the central terminations of its special nerves, and in the outer physiological effects of its stimulation. A sudden and loud sound produces as violent a start of surprise and terror as an unexpected blow; babies wink at sounds long before they do to threats at the eye, and start and begin to cry at the slamming of a door. The auditory reaction-time is as short

as the tactful, and probably for the same reason. And perhaps most interesting of all, rhythmically repeated sounds enter in through our ears and play upon our muscles for themselves, compelling us to keep time to them whether we will or not, and giving to rhythmically repeated sounds and movements the profound power over us which they undoubtedly exercise.³ And finally hearing, like touch, is a sense that is always exposed to excitation and one that can obtain no mercy when within the range of its stimuli.

The differences are, however, no less fundamental. If the ear is still a mechanical sense, it does not require immediate contact with the sound-producing object; it receives at long range the air vibrations that betray the latter's presence; its sensations, therefore, bear a more objective and impersonal character. It tells us of events in the world at large and not so much of our own states and activities.

Because of the biological advantage of this long range function, the ear has gained in keenness and in variety of sensibility until its contribution to the mental life has reached large proportions. Because of the same refinement and range of sensibility it has become also a sense of indirect perception and of sensory inferences; we infer by their sounds many things which we do not otherwise sense; to take single instances, we know it is raining by hearing the patter of the rain on the roof, and the doctor diagnoses the condition of the organs of the chest from the sounds of heart and lungs. And the most important contribution of the ear to the mental life in general—one of transcendent importance—is in a measure but a further development of this habit of indirect perception—I mean the verbal signs of language, which it has developed in coöperation with its special motor partner, the voice. Of language I shall have more to say presently; I merely mention it here, and pass on to speak of vision.

Vision, like touch, is a sense of ancient lineage and of early development in the individual life. Like hearing it is a long range sense, taking note of things not directly but through the operation of the light which they emit or reflect. Unlike touch and hearing its connection with the general muscular system is not particularly close; but in compensation it has a tolerably complex motor apparatus of

³ A slightly different example can be found in the effects of the crack of the whip and the pistol shots on the behavior of the big cats in Bostock's and other similar groups of trained animals. One can fairly see the sound stimulus playing upon the reluctant motor centers of the animals and forcing them to do in spite of themselves the things which the trainer requires.

its own. In its original function as a light perceiving sense it is as far as possible from the mechanically stimulated sense of touch; and yet it has in the retina an extended sensory surface not unlike the skin, and this, with its correlated muscles, gives vision a certain physiological analogy to touch. From very early in life also it exercises a supervisory function with regard to that sense, and in course of time comes to be very closely bound up with it, and indeed fully to justify its description as "anticipatory touch." In giving us chiefly a spatial world of things, it also stands very close to touch—much closer than does hearing. But like hearing, again, it has developed an immense power of secondary or inferential perception, far more indeed than has the ear. It thus becomes the general business sense of the mental world; and can serve on occasion directly or indirectly in some degree in place of almost any of the rest. Things look hot or cold, rough or smooth, appetizing or disgusting, one is aided in understanding a speaker by watching his lips, etc., etc.

In its own field its chief characteristic is the clearness and precision of its data. Beside it the other senses are dull and groping. It furnishes the very standard by which we measure intellectual comprehension. When a thing is as clear as day, i. e., as clear as seeing by daylight, it can be no clearer. This clear precision it probably owes, on the one hand, to the microscopic fineness of the retinal elements, and, on the other, to the dominant control that vision usually has over attention. Its contributions to the general mental life rest upon the three following qualities chiefly: that it is a long range sense, dealing with a world of outer things; that it is a sense that serves readily, though indirectly, for other senses; and that it is a sense that usually carries attention with it.

Of the senses of smell and taste there is little that need be said here. Smell is without doubt in man a survival—a sense that once stood high and is now for practical purposes almost negligible. Phylogenetically, and in certain creatures yet, it far outranks even vision as a long range sense. Under its influence it is probable that the development of the cerebral hemispheres themselves began. Time was when the nose was the organ of mind. It seems to have lost this leadership when man took his erect position and lifted his nose from the ground. For civilized man, at any rate, both taste and smell might be lost with very small inconvenience, though perhaps with some slight loss of pleasure.

Of pain and the general and organic senses we must say

a little more. To pain it belongs more than to any other sense to mould behavior directly, though it works, in a negative way, forbidding, like the demon of Socrates, certain courses of action, without recommending others except by implication. In compelling power over attention it exceeds vision itself a hundred fold; and it gives to the mental life, as to life in any of its aspects, a color of stern reality. To treat my topic fully I ought to speak of this in detail, but I am not prepared to do so; it would take a book to discuss it adequately, and I must also for the rest of my space limit myself rather to the intellectual aspect of the mental life, and neglect the emotional and the volitional.

For much the same reason I shall have little more to say of the general and organic sensations than to remind you that they resemble in quality the various forms of touch; and that with the dermal and kinaesthetic senses, they form, on the one hand, the substance of our sensory experience of ourselves, and, on the other (as the sensory basis of emotion) the staple of our life of feeling.

We have now passed in review the chief senses and have indicated some of their characteristics. Let us as the next step take two or three sorts of mental experience and see how the several senses stand in regard to them. First of all dreaming. Most dreams seem to be chiefly in visual terms. Hearing occurs frequently, but most often as the hearing of spoken words. Touch sensations are present by implication, but are not usually in the focus of consciousness. General and organic sensations are present in the same implicit way, in emotions and bodily consciousness of self, but rarely otherwise. I do not know whether images of pain are ever present in reality; and at any rate one not infrequently wonders in his dream at the painlessness of conditions that he thinks ought to be painful. In dreams as in waking life vision is clearest, and largely monopolizes attention; hearing is present as the social and language sense; and touch and organic sensibility, unilluminated by attention but nevertheless operative, form the background, especially of emotion.

If we turn from the common hallucinations of dreams to the less usual ones of the waking life, such as have been collected by the Society for Psychical Research, we shall find vision again leading, with audition second and the rest

behind.⁴ And even with the insane the only difference is the interchange of relative frequency between the ear and eye.

Of illusions (the mistaken perception of a real object as opposed to inner creation or hallucination) the eye seems to possess an almost undisputed monopoly. We hear of optical illusions till we might think there were no others. It is strange at first approach that this clearest of all senses should be thus subject to illusion, but the reason is not far to seek. The eye is easy to fool because so many of its perceptions are inferential. A little something unusual in the data or a little something omitted leads to a false inference. The eye owes its wealth of illusions to its superlative power of indirect perception. It has the defects of its virtues.

The chief characteristics of the different senses come out again in the fine arts that they subserve. Based upon sight we have the two great arts of painting and sculpture, and that part of architecture that is devoted to beauty of form. It is, however, as representative that these arts make their most direct appeal to us. The beauty of color or form alone, while not to be neglected, is a comparatively small factor. It is what the picture or statue means or suggests that moves us. With nothing more than the pure visual sensations, the visual arts would have remained on a low level—perhaps hardly above the level of simple decoration. They rise above that in proportion as by representing something they reach the broader and deeper human interests. (I am speaking here, of course, of the normal response of the naïve observer. For the artist or critic there is a special “professional” pleasure in the skill of the execution and the particular way in which the artist produces his effects. This pleasure is mediated by vision, but is, of course, intellectual rather than sensory in its quality.)

The peculiar art of the ear is the art of music—an art that makes an especially direct appeal to us (partly through rhythm and partly through the roots it sends down into the primitive emotions through its resemblance to the vocal expression of emotion). It is not compelled like the arts of form to represent something; it works upon us directly. The nearest approach to a purely visual art corresponding to the auditory art of music is to be found, as Santayana sug-

⁴ It should be noted, however, that Parish (*Hallucinations and Illusions*, London, 1902, p. 108) holds that visual hallucinations are not more numerous, but merely more frequently noticed and better remembered.

gests,⁴ in the art of pyrotechnics, i.e., fireworks, where form, color and movement are united to produce pleasure by their immediate effects and not by representing something else. Poetry, like music, belongs to the ear, but by means of language (auditory symbols in the first instance) it can appeal indirectly to all the senses and becomes representative like the visual arts. The drama gives pleasure, of course, to both eye and ear; and dancing to the eye and vicariously to the muscle sense. (Again I am speaking of the pleasure of the naïve observer; the professional has his professional pleasures as before; and in music there is for those who can follow it the musical logic in the development of the theme and of the musical form as a whole.)

The art development of the remaining senses is rudimentary and need not detain us.

You will notice that the arts that appeal to the eye depend upon its facility in sensory inference; while music, in its purest form, depends more directly on the ear and its powers of reading movement and emotional condition in the changes of inarticulate sounds.

And now the reader may perhaps be asking why I do not try to arrive at the function of the two chief senses at least, by the method of elimination—why I do not consider the mental life of those who have lost sight or hearing or both. I am ready to speak of them here, and they will serve to show us some important aspects of the mental life, but not quite in the way implied. The fact that comes out most clearly of all, when we study the cases of those who have suffered the loss of one or both of the chief senses, is the *smallness of the loss in any case for the mental life as a whole*, provided only that circumstances have been such as to supply sensory experiences of some sort in sufficient variety. Let us take extreme cases. Take Laura Bridgman and Helen Keller: What of a full mental life do they come short in? Practically in nothing but in the particular sort of bare sensory experiences which their misfortunes have cut them off from, and this is really very little; certainly they are not defective in any essential element of a full human mental life. They can think and feel as vividly and through as wide a range of feeling and thought as any one. What shall we say to this? Two things: In the first place they have retained the sense of touch which in a short-range way can serve for all dealings with the world of people and things, and, when

⁴ Santayana: *The Sense of Beauty*, London, 1896, p. 75.

trained, can serve as a language sense equal almost to hearing itself. And secondly, and this is the point to which I wish to draw special attention now, *the developed mental life is not a matter of immediate sense experiences* but of the representation and manipulation of sensory and linguistic symbols. The sensory experiences furnish materials for the manufacture of symbols; and the mental life, at least on its intellectual side, consists in manufacturing and correlating them. As a general thing it matters comparatively little what sense furnishes the material for the symbols, provided that it is furnished. In normal cases material for symbols of different kinds comes in through the different senses; especially through hearing and vision. Without special training, i.e., without the furnishing of touch language symbols, etc., persons with defects like those of Laura Bridgman and Helen Keller are predestined to very imperfect mental development.

The symbols derived from the different senses long bear the marks of the senses from which they spring. It is to the characteristics of some of these symbols and the manner of their development that I wish to devote the rest of my space.

First let us start with simple perceptions and see how a symbol of some abstractness gradually grows up. To perceive a thing is in some sense to take it out from its setting and to regard it, in attention at least, as a separate thing. In those sense fields where a considerable variety of sensation is possible, the whole mass tends of itself to break up into separate groups of a more or less permanent nature, and instead of a variously featured whole we get a mass of separate things. We see a room full of furniture with pictures on the walls and books on the table, for example, and not a mere variegated visual field. But of these separate things, even, we do not get photographic copies. We get instead mere sketches in which certain aspects are sharply and clearly brought out, and others are barely indicated or wholly omitted. The sense groupings are determined in a general way by our environment, but they get a special perspective in their parts that is dictated by our human needs and purposes. Things are perceived with an implied meaning, and that meaning is dictated as long as we are on the common practical level, by what we can do with the things or what they will do to us. It is said that a savage's first questions with regard to a new object are apt to be; "Will it hurt me?" and "Can I eat it?" This is doubtless a slander

on the savage; nevertheless it caricatures a characteristic mental attitude and one that leaves its impress on all our percepts. We look at a chair as something to sit upon, and we usually neglect the fact that it is also a wooden object and may, in case of need, be used for making a fire. We look upon sheep in the pasture and mutton on the table as quite different things, neglecting in each case what is prominent in the other.

These last examples are cases of what psychologists commonly call apperception—the perception of a thing with a meaning—but perception and apperception are in reality the same thing and pass into each other by imperceptible gradations. There is no essential difference in kind, merely one of complexity, of degree, between the simplest case of perceiving a taste or smell and apperceiving a social action as one which is in the long run detrimental to the common good. Perception and apperception consist essentially in omitting certain aspects and retaining and emphasizing others, omitting those that are unimportant for the matter in hand and stressing those that are important—those that have (or constitute) the meaning.

And we need not stop here. This is the same sort of selective action that is operative in the formation of all concepts and abstractions, or symbols, of objects and relations. We abstract, or pick out by attention certain aspects of our knowledge about chairs for our common dealings with them, we neglect others. We take certain essential aspects of concrete cases of just actions to form our concepts of abstract justice, and leave those that are not essential. We take certain aspects of actual physical objects to form our concepts of matter, and we leave out the rest. We take certain other aspects of groups of things as the basis of our abstract concepts of number, and neglect all the other aspects. And so with all the rest. Only one further step is necessary to the completion of general concepts, however general and however abstract; and this is one that often takes care of itself, namely, that the instances in which like aspects appear should somehow come together and be associated, and then get some sort of a distinctive name or language symbol.

This is as far as we need to follow the process at the moment. When we have once gotten our name or language symbol we can do pretty much what we like with the concept so long as we do not separate it from its definite meaning, and so long as we keep the way open for a return to the concrete experience when we need. Ribot, if my memory

serves me right, has compared the whole process to the development of the different means of managing commercial exchanges. At first there is simple barter ; things are swapped for other things. Then one of these, perhaps the most frequently exchanged, is taken as a measure of value ; so many cows, for example, for so much grain, or so many for a piece of land. Later bullion is substituted for cows, as more portable and more universally desired ; then by and by coined money. Later still come paper money, bank checks and other evidences of credit. These add greatly to our convenience, but one and all have value only in so far as they rest upon an adequate basis, and can, in case of need, be turned into the various concrete valuable things for which they stand. Similarly with the abstractions and their symbols ; they facilitate thinking, but have a genuine meaning only as they can be reduced in case of need to the concrete experiences from which they were originally drawn.

Now let us return to our chief sense modalities and ask for the special concepts that each furnishes, that we may see how far these carry the marks characteristic of their origin, as I have said they do. From touch and sight in coöperation we get our conceptions of space and movement ; from touch and the kinæsthetic group of senses the fundamental qualities of matter—impenetrability, mass, weight, inertia, force—and from the kinæsthetic group, in free or hindered movement, our sense of personal freedom or constraint. A blind and deaf man might be a physicist ; it is doubtful if a totally anaesthetic and paralysed man could be, because he could not frame the fundamental physical ideas, or if he would have any idea of personal freedom. From touch also come our fundamental ideas of reality. That which can be touched and handled is real for any doubting Thomas ; that which can be seen or heard but not touched is a ghost. If we all, in spite of efforts to the contrary, take matter as the prime type of reality and refute Berkeley by kicking a stone, it is because we instinctively fall back upon our primal sense of touch.

Touch furnishes us, as I have said, a considerable part also of that mass of fused sensations that constitutes our perceived selves, though vision also and the other senses do something. It is here that the feelings of double contact are important. From our own persons we get double contact sensations, from all else single. We feel and see parts of ourselves, and we live in a peculiar way in the parts of our persons that we can feel and see. One of Du Maurier's

pictures in *Punch* represents a little girl trying not very successfully to tie her sash behind her back. She finally appeals to her aunt who stands by. The aunt replies: "Why, Alice, you are such a big girl now, you ought to be able to tie your own sash." To which the little girl retorts: "How can I, Aunty, when I'm in front." We are all of us chiefly in front. And yet even touch itself furnishes but the outer and less important part of our empirical selves. A deeper self is the self of feeling and emotion, the self that loves and hates, that strives and aspires, that enjoys and suffers; and for this another group of senses is chiefly responsible—that inner group of general or organic sensations. It is of the reverberations of excitations within the field of these inner senses that the moving part of our emotions is constituted. The loss of feeling robs us of all that part of ourselves that makes life or anything else valuable. And that part of ourselves we owe chiefly to our general and organic sensations.

To sum up briefly I may say that we get from the chief senses singly or in coöperation four characteristically different abstractions: From touch we get the world of space and material reality, and force acting upon us; also, from motor touch, energy, active efficiency and freedom; from vision we get space and the world of things, though in a somewhat different way from that in which touch gives them to us; from hearing we get our symbolic machinery of thought; from the general and organic senses, our most intimate intuitions of ourselves and the basis of our emotions.

We can tell whether these bear the marks of their sensory origin only by thinking of the meaning of them and seeing whether they still carry a sensory suggestion. Matter and solid reality, when I myself try to give them definite meaning, suggest at first something visual and then if pressed further something palpable, something that resists movement. Freedom suggests free swinging of the arms and body movements, and efficiency something like a physical pushing. Unfilled space, if taken as remote, is that which can be seen through, and, if near, perhaps in addition that through which the hand may be thrust. The feeling self resides for me in the chest, or at least "in front." These are but a few illustrations, but there can be little question that these abstractions all carry the marks of their origin, or still lie close to it; and it is but natural that they should do so, since they have been reached by a process of subtraction of temporarily unimportant aspects. These special cases are of course all instances in which we have been trying to get a somewhat

concrete meaning for our abstractions, to exchange our paper money for coin. But at the same time we must remember that it is only as we can ultimately reduce them in some such way that they really have any meaning at all.

But now assuming that sensory marks remain upon most abstractions, and sensory experiences furnish them with such meaning as they have, what follows from it? I reply that certain very definite limitations follow from it. I tried in a paper several years ago⁵ to show that the symbols (or abstractions or concepts) of physics had an underlying basis in the experiences of the dermal and kinæsthetic senses, and for that reason physics could not be expected ever to be able to furnish a full and satisfactory explanation of psychic experiences derived from other sense modalities; in brief, that we never could get a satisfactory explanation of the whole psychic life in terms of matter and motion, the fundamental concepts of physics. We cannot, for example, expect to explain the quality of a taste or a smell or a pain in terms of sensations of pressure or of the kinæsthetic group, much less all psychic life. The concepts of physics tend, in a word, to state all physical phenomena in terms ultimately reducible to dermal and kinæsthetic experiences, and by that very fact physics is prevented from explaining anything that lies outside the field of dermal and kinæsthetic experiences, because of the impossibility of translating one sort of sensation into another sort. It is *disparateness in sensory origin of the concepts* that makes the great gulf which has been said to lie between the self and the external world. We can leave out what we like in forming any abstract concept, or symbol, but we cannot leave out everything; and what we retain fixes the field in which the laws that we reach by use of that abstraction will prove necessarily applicable.

We can in some cases indeed transfer meanings and use symbols derived from one sense as carriers for meanings derived from another sense, as for example, when we treat geometrical relations by algebraical symbols in analytical geometry. But this is merely a transfer of the language signs, i.e. of the signs of symbols, and not of the original symbols themselves. In every case the meaning must come from somewhere (i.e., ultimately from some sensory experience) and the meaning then gives limits to the symbols as if they had originated along with it.

What I have just said of the limitations of physics is true, however, only in so far as physics finds its problems in

⁵ *Psychology and Physics*, Psy. Rev. X, 1903, 105-119.

dermal and kinæsthetic experiences, that is in the physical world as we know it. There may come very likely a stage at which a metaphysical or transcendental physics will arise in which the symbols will be varied arbitrarily, and then the specific marks of the physical senses may be left out. Mach, in his little book on "Space and Geometry," suggests such a development.⁶ Something of the kind seems actually to have taken place already in the symbolism of mathematics, where the abstractions have been carried to a very high degree of tenuity and where symbolism has been most diligently elaborated. In the work referred to, Mach shows in interesting fashion how geometrical space has grown up from our original physiological apperception of it, and how the science of geometry has developed from the practical necessities of land surveying and other measurements, suffering gradual transformation also, until now it is a science of pure space—a science that criticizes and experiments with its own concepts, and gives us geometries of spaces that we never experience—spaces that are curved, in which parallels may meet, and in which there are four, five or n dimensions. These are of course as far beyond immediate intuition in thought as they are beyond direct perception by the senses. It has become a mere question of the relations of symbols to which certain meanings (and not necessarily spatial meanings) have been reserved, while other and practically necessary ones have been omitted.

In the modern theories of number mathematical symbolism has perhaps reached a still higher pitch of abstraction. There, it would seem that everything has been reduced to a concept of sequences, or as we might phrase it psychologically, to concepts of change according to a certain law, or principle. It need not be change of direction, nor of quantity, nor of quality, but simply change according to some plan. And the interesting point for psychology is that the mathematicians seem here to have been able to shake off at last the special marks of the outer senses, and to have retained as the sole content of the concept attenuations of a purely inner and subjective character, i.e., aspects of sensations in general. The supersensual developments of geometry above referred to seem to have reached nearly this same pitch. The mathematicians would say at once that the formulas of transcendental geometry apply to any sorts of manifolds with aspects related in the ways represented by the symbols, not to space alone. Considered psychologically the progress of the mathematical con-

⁶ Mach: *Space and Geometry*, tr. by McCormack, Chicago, 1906.

cepts has been from those distinctly empirical and of the senses, by gradual elimination of the sensory elements, to those that are distinctly reflective—distinctly of the mind, to mental forms in the sense of Kant. They are symbols of relations, perceived by the inner eye of conscious attention, not of external objects of sense. The progress has been from without inward. And this tendency is inherent in the development of all concepts provided that they are pushed far enough and made abstract and general enough, i. e., if enough is left out of them. Beyond these general subjective forms, however,—fundamental characteristics of all varieties of sensory experience,—even mathematical abstraction cannot go, because to leave out these would be to make the concepts entirely empty and void of meaning. Beyond these lie only the fundamental conceptions of pure logic, which are by profession contentless and for which the experience of cognition is in itself a sufficient psychological source.